P1.20 **AN ANALYSIS OF SYNOPTIC PATTERNS ASSOCIATED WITH STRONG NORTH TEXAS COLD FRONTS DURING THE 2005-06 COLD SEASON**

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1. INTRODUCTION

The cold season across North Texas is characterized by mild weather with sporadic cold outbreaks of varying intensity and duration. As strong weather systems move across the Central and Southern Plains, North Texas is often affected by significant temperature fluctuations, wind, rain, and/or winter precipitation. The numerical models sometimes have a difficult time resolving the timing and details of these systems, including timing and strength of fronts. However, regional and global models have better success forecasting the synoptic scale features of weather systems, such as the intensities and positions of long wave troughs and ridges.

The motivation for this project was to learn which large scale signals and patterns in observed and model data were best correlated with strong frontal passages in North Texas. Through recognition of these signals and patterns, forecasters will be better able to predict the strength and timing of these features that have significant impacts on sensible weather.

In order to learn which large scale patterns were associated with strong fronts, the origins of the airmasses behind the fronts were studied along with upper level patterns before, during, and after frontal passages. In addition, geopotential height, temperature, and pressure anomalies associated with the synoptic patterns were analyzed to determine the relative significance of the features compared to long-term averages.

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2. HYSPLIT TRAJECTORIES

Airmasses associated with strong cold fronts are closely related to their source region, as well as the three-dimensional trajectory of the representative air parcels within the airmass. A trajectory is defined as a curve in space tracing the points successively occupied by a particle in motion. This study used a trajectory model to help determine airmass source regions and the associated three dimensional trajectories of theoretical air parcels. HYSPLIT, which stands for Hybrid Single Particle Lagrangian Integrated Trajectory, is a model which may be used to compute single air parcel trajectories, either forwards or backwards in time (Draxler and Hess 1997). The HYSPLIT model was used in this study and was easily accessible through the Air Resources Laboratory website.

Within the framework of HYSPLIT, archived data was run using the Global Data Assimilation System (GDAS) dataset to map backwards trajectories for all “strong” fronts which affected North Texas during the 2005-06 cold season. Strong fronts were subjectively defined as having a 24 h temperature change of at least 8 degrees C (15 degrees Fahrenheit) at Dallas/Fort Worth International Airport (DFW). The GDAS dataset was preferred over other available datasets since its domain included all of the Northern Hemisphere and missing data during the period of study was minimal.

Timing of frontal passage was determined by looking at DFW Automated Surface Observing System (ASOS) observations and the Daily Weather Map series. Backward trajectories were run with end times approximately 12 to 18 h after frontal passage at DFW. The length of the backwards trajectories was 192 h, or 8 days. Once the strong fronts were identified and their trajectories mapped, they were then classified as either Arctic or Pacific by looking at the origins of the backward trajectories. There were a total of 8 strong Arctic and 11 strong Pacific fronts which

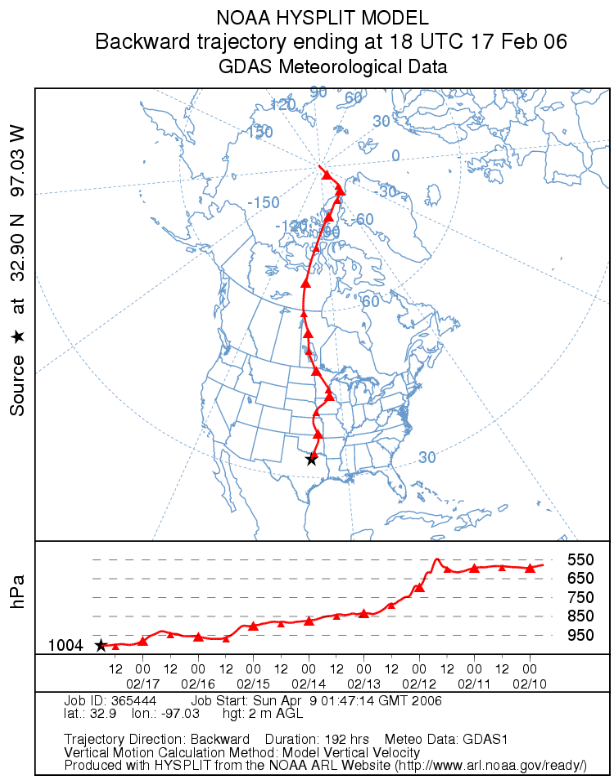

Fig. 1. HYSPLIT backward trajectory plot for 18 UTC 17 February 2006. The ending time of this trajectory is approximately when the coldest air was reaching DFW.

affected North Texas in the 2005-06 cold season.

Figure 1 shows an example of a trajectory plot from an Arctic front that passed DFW during the afternoon on 16 February 2006. The red line tracks the theoretical path of the air parcel which arrived at DFW at 1800 UTC on 17 February 2006 at a height of 2 m. The time increment between the large triangles is 24 h. Thus, the trajectory path shows that the air parcel at DFW originated near the North Pole eight days prior. The chart along the bottom shows the parcel's vertical profile, originating around 575 hPa at the beginning of its journey. By the time it reached DFW, the parcel had undergone substantial subsidence, with a pressure of 1004 hPa at the end of its trajectory.

Parcels with a history of strong subsidence were common with the Arctic fronts, similar to the findings of Walsh et al. (2001). The subsidence can be explained in part by the parcel's southward path along the westward or subsident side of the associated upper level lows. The average temperature change of the parcels during the eight days was around thirty-three degrees Kelvin. Table 1 shows the average parcel ambient temperature and parcel pressure for the Arctic fronts at the parcel's origin and at its destination (DFW).

Table 1: The average temperature and pressure for air parcels behind Arctic fronts at the beginning and end (2 m AGL) of their trajectories. Values are based on output from HYSPLIT backward trajectories.

	Avg Parcel Ambient Temperature (K)	Avg Parcel Pressure (hPa)
Trajectory Origin	246	694
Trajectory End (DFW)	279	998
Difference	33	304

The front corresponding to the trajectory in Fig. 1 was the strongest Arctic front of the season. The 24 h temperature change at DFW associated with this frontal passage was 27 C (48 Fahrenheit). Low temperatures associated with this front did not set any records however, as temperatures were well above normal ahead of the front. An hourly temperature plot and surface chart from the 16 February 2006 Arctic front case are shown in Fig. 2 and Fig 3.

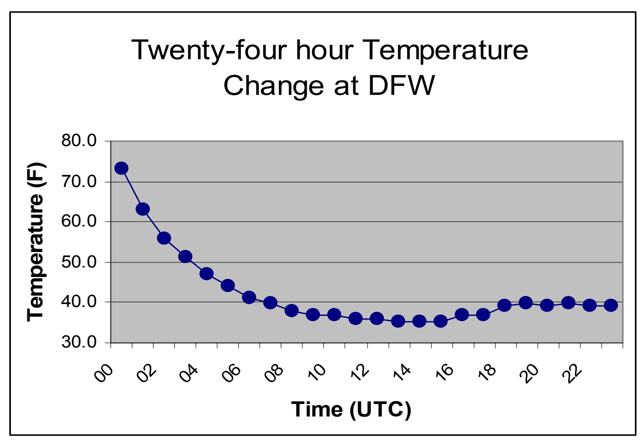

Fig. 2. Graph showing 24 h temperature change at DFW starting at 00 UTC on 17 February 2006 during the strongest Arctic front of the season.

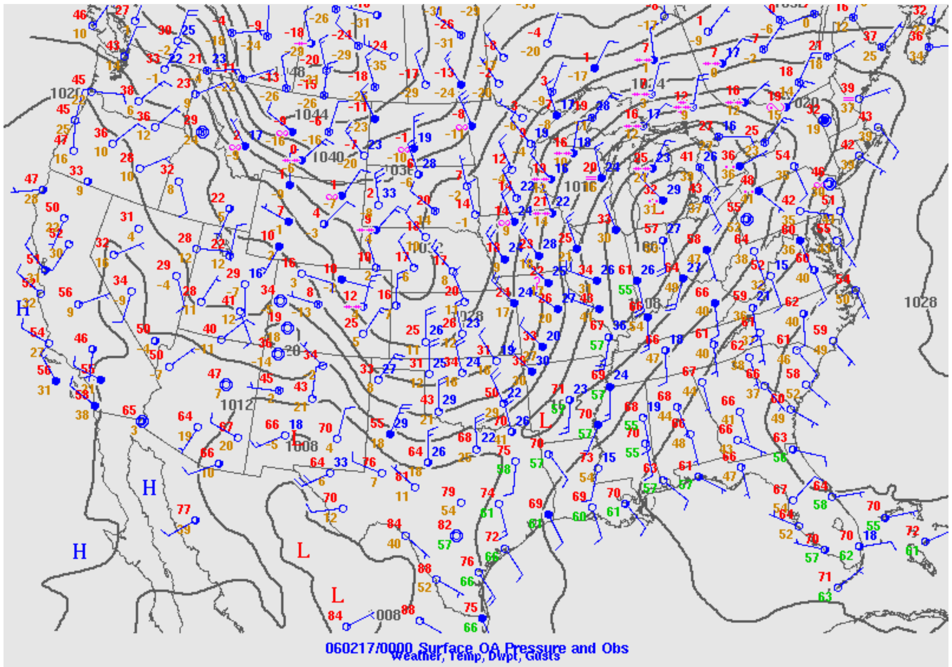

Fig. 3. Surface plot and MSLP analysis valid at 00 UTC 17 February 2006. The Arctic front extended from southern IL across AR to just south of DFW.

Trajectories associated with a relatively weak Arctic front will now be examined in order to compare and contrast with the stronger Arctic front. Figure 4 shows a trajectory behind a front which passed through North Texas early on 6 October 2005 with a 24 h temperature change of 12 degrees C (22 degrees Fahrenheit). This is weaker than most of the other Arctic cases, most likely due to its early season appearance. The trajectory associated with this front is not too dissimilar from the stronger example. They both originate north of the Arctic Circle, although the stronger front's trajectory began farther north. The weaker front's trajectory has more curves and turns, possibly indicating that the airmass was less dense than its stronger counterpart. In addition, the vertical profile of the trajectory in Fig. 4 indicates a starting height that is slightly lower than that of the stronger case.

A listing of all strong fronts that affected north TX during the 2005-06 cold season can be found in Appendix A. A lack of strong Arctic fronts during January is rather conspicuous. North Texas was in a severe drought, and the upper level pattern over the Southern Plains was very progressive. Therefore, it is not a surprise to find that the strong fronts which affected North Texas during January were all of Pacific origin. The passage of these fronts, with their accompanying dry air and gusty northwest winds, contributed to the spread of numerous wild fires across north TX.

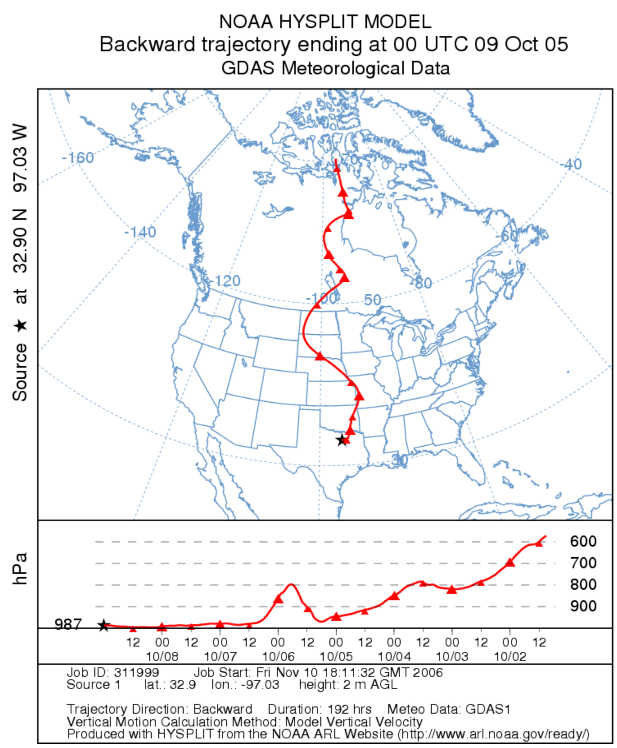

Fig 4. Same as Fig. 1, except for a weaker Arctic front at 00 UTC on 09 October 2005.

3. GEOPOTENTIAL HEIGHT, TEMPERATURE AND PRESSURE ANOMALIES

Once the parcel trajectories behind the front were examined, the surface and upper level maps corresponding to each front were studied. Specifically, sea level pressure charts, height charts at 500 hPa, and surface air temperatures were considered. In addition, the anomalies, or differences from normal, were also examined for these parameters. Composites, means, and anomalies were plotted using the NOAA/ESRL Physical Sciences Division website (http://www.cdc.noaa.gov/), which used NCEP/NCAR Reanalysis (Kalnay et al. 1996) and other datasets with means based on the period 1968-1996. The eight Arctic cases were grouped first according to the parameter (MSLP, 500 hPa, or surface air temperature), and then by day. For example, all the 500-hPa Day 1 maps were co-located, and therefore easily compared. Day 1 for this purpose is the day of the frontal passage. Day 2 is 24 h prior to Day 1; Day 3 is 24 h prior to Day 2, and so forth. In this way the meteorological parameters and their associated anomalies could be studied several days prior to the frontal passages. This procedure could help uncover large scale signals that forecasters could use to better predict cold outbreaks.

Konrad (1995) examined the relationships between cold air outbreaks (CAOs) and certain synoptic features in North America. Of interest were his findings which linked the strength of temperature minimums, surface anticyclones and cyclones, and 500- hPa troughs and ridges to the intensity of the CAO. Using a statistical program, he calculated the correlations between the aforementioned parameters to the CAO from the time of the outbreak to several days prior. For example, he found that the surface anticyclone correlation was highest two days prior to the outbreak.

Table 2 shows the average of the highest anomalies for sea level pressure, 500-hPa heights, and surface air temperatures for the eight Arctic cases. The anomalies for each day were confined by latitude ranges or rings. The latitude range for each period was derived by using the results of the parcel trajectories. For example, four days prior to the passage of a strong Arctic front at DFW, the highest positive sea level pressure anomalies, the coldest surface air temperatures, and the highest negative height anomalies at 500 hPa would most likely be located far to the north, say between 60° and 70° North latitude. The longitude of the anomaly was not considered. As the strong Arctic front approached the Southern Plains, with frontal passage around two days away from DFW, the highest anomalies would probably be between 40° and 50° North latitude. This pattern was followed for four days prior to each frontal passage.

Table 2: Anomalies of MSLP, 500-hPa height, and 2-m air temperatures for all eight Arctic cases are labeled 'mean'; anomalies for the stronger and weaker cases are labeled 'stronger' and 'weaker'.

Day	**Latitude Range (degrees N)**	**MSLP Anomaly (hPa)**	**500-hPa Height Anomaly (m)**	**Surface Air Temperature Anomaly (°C)**
4	**60-70**	***Mean*** **30** ***Stronger*** **35** ***Weaker*** **15**	***Mean*** **-210** ***Stronger*** **-270** ***Weaker*** **-120**	***Mean*** **-13** ***Stronger*** **-9** ***Weaker*** **-11**
3	**50-60**	***Mean*** **26** ***Stronger*** **40** ***Weaker*** **20**	***Mean*** **-274** ***Stronger*** **-300** ***Weaker*** **-180**	***Mean*** **-11** ***Stronger*** **-13** ***Weaker*** **-6**
2	**40-50**	***Mean*** **22** ***Stronger*** **35** ***Weaker*** **18**	***Mean*** **-259** ***Stronger*** **-270** ***Weaker*** **-180**	***Mean*** **-10** ***Stronger*** **-13** ***Weaker*** **-12**
1	**30-40**	***Mean*** **13** ***Stronger*** **25** ***Weaker*** **10**	***Mean*** **-214** ***Stronger*** **-180** ***Weaker*** **-180**	***Mean*** **-10** ***Stronger*** **-15** ***Weaker*** **-8**

It may be helpful to compare the findings in this paper with the findings in Konrad's paper, even though Konrad did not examine anomalies. First, according to Konrad, the correlation between surface anticyclones and CAOs should roughly stay the same between Days 4 and 2, with only a slight increase on Day 2. However, the findings for North Texas were that the positive sea level pressure anomalies tended to be highest on Day 4 and decrease thereafter. Looking at the individual fronts, five cases had a decrease in this anomaly from Days 4 to 2, two had an increase, and one stayed the same.

Similarly, Konrad found 500-hPa patterns correlated best two days prior to the CAO, with a much higher correlation than that of the sea level pressure fields. Findings for North Texas were similar in this case. Looking at the 500-hPa average height anomalies in Table 2, the anomaly is stronger on Day 2 than Day 4. Indeed, seven out of eight cases examined showed this trend. However, it is interesting to note that the peak is on Day 3. According to Konrad, the 500-hPa trough's correlation with the CAO continues to decrease from Day 2 to Day 0. This is also corroborated over North Texas, as five of the cases studied had anomalies which weakened from Day 2 to Day 1, with none of them strengthening.

Konrad looked at "Temperature Minimums" in his paper to study CAOs as opposed to the surface air temperatures used in this paper. Since these parameters are not identical, any comparisons between the temperatures studied in this paper and the temperatures in Konrad's paper will be suspended at this time. What is noticeable in Table 2 is that the highest mean surface air temperature anomalies are greatest on Day 4, and decrease every day thereafter until frontal passage.

Two cases will be presented to show the dichotomy between a relatively weak and a stronger Arctic front. These cases will be the same ones analyzed in the previous HYSPLIT section. Table 2 shows the anomalies associated with the strong Arctic front from 16 February 2006.

Compared to the averages for all of the Arctic fronts, the stronger front has higher MSLP anomalies for all four days. Looking at Table 2, the highest anomaly for this case is on Day 3, as it was for the means. The highest 500-hPa height anomalies from the stronger case dwarf the means for Days 4-2, but are 34 m lower than the mean on Day 1. Like the mean of the Arctic cases, the 500-hPa anomaly for the stronger front case peaks on Day 3. The biggest difference between the mean 500-hPa anomalies and those for the stronger front case occur on Day 4, when the stronger case's anomaly is 60 m higher. For Days 3 through 1, the differences are much smaller. Perhaps the magnitude of the 500-hPa anomaly on Day 4 is a signal that forecasters could use to predict a strong Arctic frontal passage. There are two real-time anomaly websites which may be useful for this purpose and those sites are listed in Appendix B.

The daily trend in surface air temperature anomalies for the stronger case are generally opposite of the trend of the mean of the eight Arctic cases. The greatest temperature anomalies with the stronger case are noted on Day 1, while the greatest temperature anomalies of the mean is on Day 4. By Day 1, temperatures anomalies for the stronger case are over five degrees C colder than the mean.

The weaker front case is just that, with MSLP, 500-hPa height, and surface air temperature anomalies generally much lower than the mean for all the Arctic cases. The biggest difference between the weaker case and the mean was noted in the 500-hPa anomalies at Days 3 and 4 and the MSLP anomalies at Day 4.

Overall, anomalies from the weaker Arctic front tended were substantially different (lower) from the mean at Days 3 and 4. Within 48 hours of frontal passage, anomaly values for the weaker front approached the value for the mean.

4. PACIFIC CASES – TRAJECTORIES AND ANOMALIES

The strong Pacific fronts from the 2005-06 cold season were not studied in as much detail as the Arctic fronts. One reason for this was that the Arctic fronts were considered to have greater impacts and were studied first. This section gives an overview of the research that was conducted with the Pacific fronts.

4.1 Trajectory from 15 December 2005

Figure 5 shows a representative trajectory from the Pacific cases. Most of the trajectories originated in the northern Pacific Ocean, came ashore in Canada, and were guided into the Central and Southern Plains east of the Rocky Mountains. Lift associated with the mountains is obvious in the vertical cross section of the trajectory in the bottom graph. This feature was present on all the Pacific trajectories.

4.2 *Pacific composite anomaly charts*

Composite anomaly charts were constructed from the 11 strong Pacific fronts in this study. Sea level pressure charts, height charts at 500 hPa, and surface air temperatures anomalies were mapped, just as in the Arctic cases, using . Then, the mean (composite) anomalies were plotted based on the parameter and day. For instance,

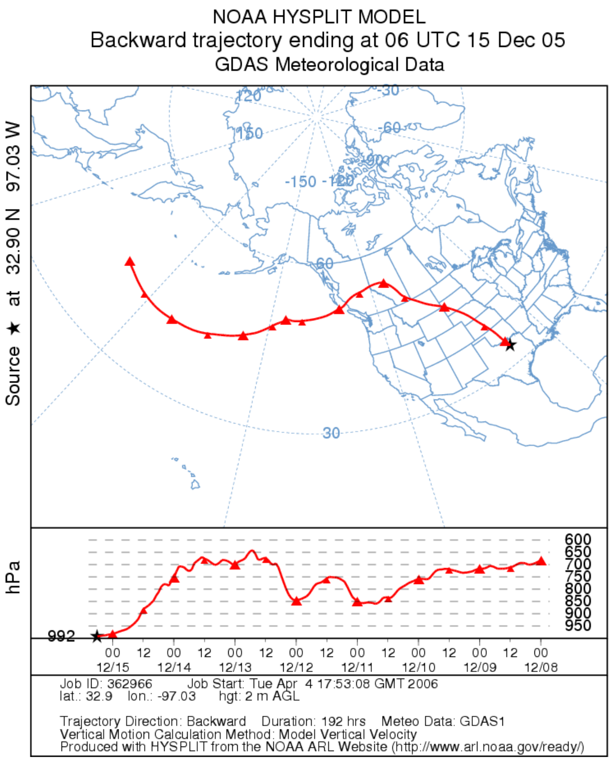

Fig. 5. Same as Fig. 1 except for a Pacific front on 06 UTC 15 December 2005.

the 500-hPa composite anomaly of all 11 strong Pacific fronts on Day 4 (4 days before frontal passage) is shown in Figure 6.

The composite anomaly chart in Figure 6 shows significant negative values over the Gulf of Alaska, the northwestern United States and western Canada. This indicates the presence of an upper level low or significant trough in this area four days prior to the Pacific frontal passage at DFW. An area of rather weak positive height anomalies is positioned over the central United States and western Canada. The other days in this sequence, Days 1-3, depicted negative height anomalies approaching the central U.S. that weakened as they moved into the Southern Plains.

5. SUMMARY AND CONCLUSIONS

This study examined 8 Arctic fronts and 11 Pacific fronts which affected North Texas during the 2005-06 cold season. HYSPLIT was used to examine the trajectories and origins of the cold air behind the fronts. It was shown air parcels behind Arctic fronts had a history of strong subsidence on their way to DFW. On average, parcels warmed 33 deg K with a pressure increase of 304 hPa by the end of their trajectories at DFW. Upper level maps were studied at roughly the time the coldest post-frontal air reached DFW for each front. Anomalies were then computed at these times for 500-hPa heights, mean sea level pressure, and surface air temperatures. In addition to looking at the average anomalies for all the Arctic cases, one exceptionally strong Arctic front and one weaker Arctic front were examined. All of the cases were compared and contrasted with the findings in Konrad's paper on CAOs. The eleven Pacific cases were inspected to a lesser degree. One Pacific trajectory in particular was shown and discussed. Composite anomaly charts of the Pacific cases were also mentioned, and one of these charts was presented.

The magnitudes of both MSLP and 500-hPa height anomalies seem to be the best discriminators of stronger versus weaker Arctic frontal passages in this study. Forecasters may be able to use the magnitude of MSLP anomalies and 500-hPa anomalies to predict the strength of cold frontal passages three to four days in advance.

6. ACKNOWLEDGEMENT

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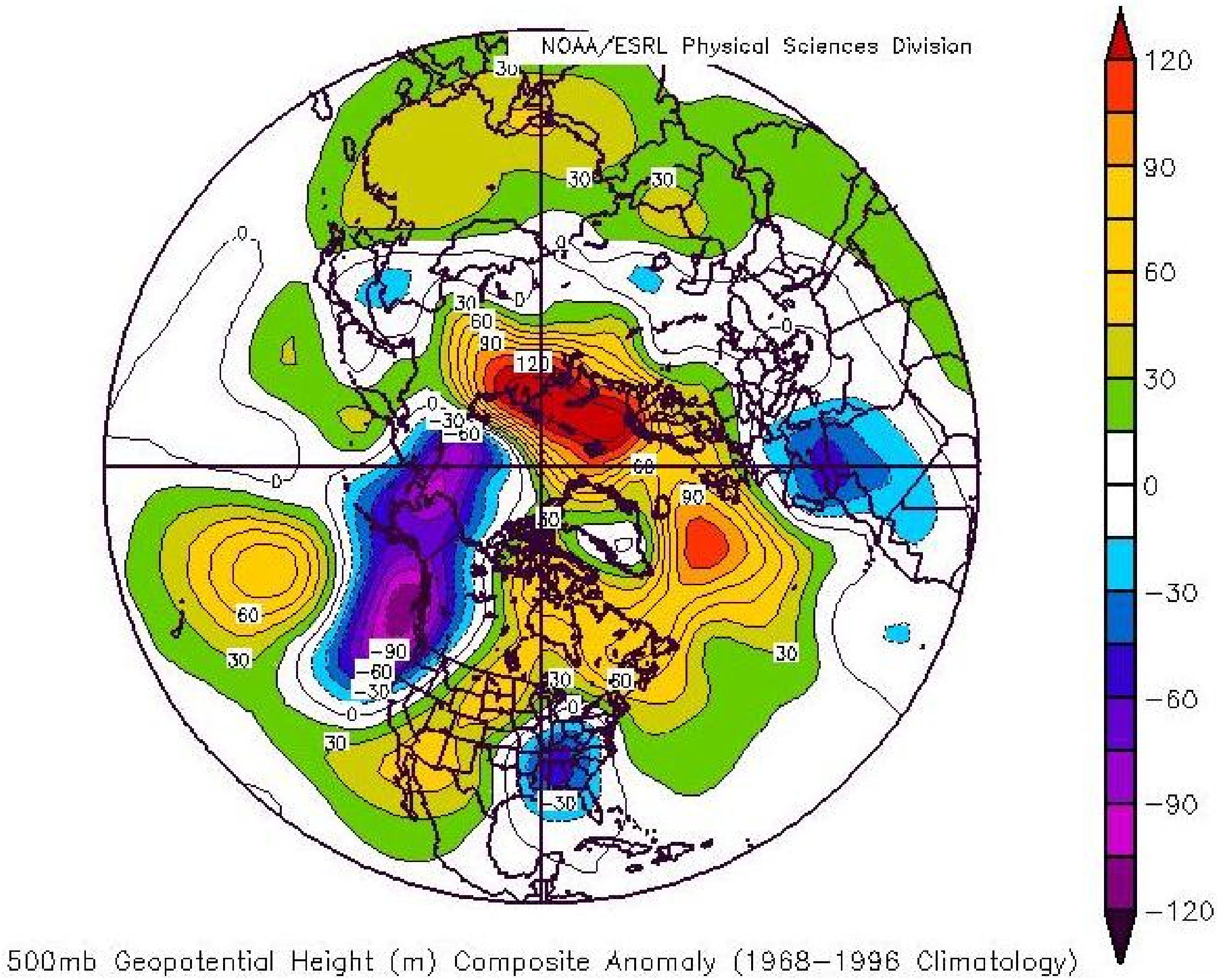

Fig. 6. 500-hPa Composite Anomaly of all strong Pacific fronts on Day 4. Note the maximum of -90 to -120 m centered in the Atlantic Ocean near the Canadian coast. (Image provided by the NOAA/ESRL Physical Sciences Division, Boulder CO, from their Web site at http://www.cdc.noaa.gov/)

Appendix A: Chronological list of all strong fronts from the 2005-06 cold season.

FROPA Date/Time	Type	24-hour Temperature Change °C (°F)	GDAS Trajectory Date/Time
10/06/05 06 UTC	**Arctic**	12 (22)	10/09/05 00 UTC
10/23/05 11 UTC	**Arctic**	8 (15)	10/25/05 00 UTC
11/15/05 15 UTC	Pacific	15 (27)	11/16/05 12 UTC
11/28/05 13 UTC	**Arctic**	14 (25)	11/30/05 12 UTC
12/03/05 22 UTC	**Arctic**	22 (39)	12/05/05 12 UTC
12/07/05 11 UTC	**Arctic**	15 (27)	12/08/05 12 UTC
12/14/05 14 UTC	Pacific	8 (14)	12/16/05 12 UTC
12/27/05 22 UTC	Pacific	8 (15)	12/28/05 12 UTC
01/04/06 12 UTC	Pacific	11 (20)	01/05/06 18 UTC
01/09/06 15 UTC	Pacific	14 (26)	01/11/06 06 UTC
01/13/06 02 UTC	Pacific	12 (21)	01/15/06 06 UTC
01/17/06 02 UTC	Pacific	11 (20)	01/17/06 12 UTC
01/20/06 21 UTC	Pacific	12 (21)	01/21/06 18 UTC
02/06/06 04 UTC	Pacific	10 (18)	02/08/06 18 UTC
02/10/06 16 UTC	**Arctic**	9 (17)	02/12/06 18 UTC
02/16/06 23 UTC	**Arctic**	27 (48)	02/18/06 00 UTC
03/02/06 10 UTC	Pacific	12 (21)	03/04/06 06 UTC
03/13/06 08 UTC	Pacific	18 (33)	03/13/06 18 UTC
03/21/06 02 UTC	**Arctic**	13 (23)	03/21/06 18 UTC

Appendix B: Real-time anomaly websites.

http://eyewall.met.psu.edu/ensembles/index.html

http://www.hpc.ncep.noaa.gov/training/SDs/

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